REDUCTION OF PRIMARY ENERGY IN THERMO - HYDRAULIC INSTALLATION WITH ELLIPTIC SOLAR COLLECTOR

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Abstract. In this paper, it is presented the optimisation of heat installation constituted of the condensing boiler equipped by the semi-rapid boiler for the annual production of sanitary warm water. For this purpose it was connected in series to an elliptic solar collector with incorporated accumulation. The combination of the system boiler - elliptic solar collector with incorporated accumulation allows to get the maximum absorption of the three components of the solar radiation in a full day with the least cost of installation. The results of the optimization lead to a maximum daily energy received from all tree components of the sun radiation, and also to avoid the freezing at total reflection and the superheating phenomenon in winter and in summer period, respectively. The thermo-economic calculation of introduced comparison, among an installation without solar collector and one with the elliptic solar collector to incorporated accumulation it underlines the reduction of burnt fuel and the economy gotten through this system.

Keywords: heating installation/reduction of energy/thermal optimization/solar collector/solar energy

1. INTRODUCTION

The studied installation is constituted by a condensing boiler endowed by a semi rapid boiler with small accumulation of 14 lifters. The combined type of condensing boiler, it is appropriate for the heating and for production of warm sanitary water for the whole year, for a house of 120 m² lived by a family of 3 people. The boiler for production of warm sanitary water is connected to an elliptic solar collector with accumulation incorporated. The installation is analyzed appraising the reduction of the consumptions of methane burnt under operational conditions, at the end of the period of heating and in the six successive summer months.

In the big part of the installations, the solar integration happens through plane solar collectors or heat pipe. The heat transfer to a reservoir to accumulation with double serpentine, it to be destined to the solar circuit is filled by a mixture of water-glycol antifreeze. Through an electronic regulator the difference of temperature is valued (8-10°C) among the solar collectors and the reservoir to the purpose of to operate the pump to transfer the heat to the boiler (L. Rocco and al., 1994). This system results to be still enough expensive, even if in these last years, the costs of installation have become more convenient because of the increase of the price of the oil. The amortization of such installations would result acceptable only with the help of government incentives.

Besides, for acceptable choices aesthetically (for example the position in adherence to the roof of the building), it often forces us to renounce big part of the available solar energy.

Therefore that the importance of a installation simple hydraulically is born, more economic but that at the same time both technologically and energetically advantageous.

The analyzed installation, has been carried out in a place of northern Italy to the latitude of \( L = 45^\circ \), and it is represented in figure 1 where is been installed a condensation boiler equipped of integrated boiler connected to a solar collector with accumulation.

The figure 1 shows the constitution of the installation: the condensing boiler 1) that it works to methane comprehensive of boiler of small capacity 3) equal to 14 lifters, with semi rapid heat exchange.

The solar collector 2), he is hydraulically connected to the boiler 3), in such way that the same receives water preheated by the solar collector always for the whole year.

When sanitary water is preheated, the elliptic solar collector receives cold water from the city net and the boiler receives water preheated by the solar collector. In this way, during the winter, the boiler will have the assignment to heat the water in the small boiler of the difference of temperature in comparison to the value of use (generally 40°C) obtained mixing the water flow exit of the same boiler. If the water temperature in the elliptic solar collector overcomes the temperature of the...
distributed water, the condensing boiler is maintained
down to 38°C through the command established by a probe
of water. The elliptic solar collector with accumulation, in this case,
is tilted by an angle of 30° (for Italy northern with
latitude 45°). Its behaviour is as that of a common
boiler, because, the heat accumulated by the volume of
water (Vc = 135 l) it is stratified it toward the tall part
of the solar collector. During a drawing continuous of
the warm sanitary water, the cold water enters in the
low part of the solar collector and it will have the
tendency to remain in the low part without mixing him
completely with the rest of the mass.

This allows to obtain some water to a constant
temperature, with continuous drawing of around the 70%
of his volume. From this moment, the temperature of the
water of the elliptic solar collector decreases quickly.

To facilitate the understanding of the following eco-

nomical analysis, introduces in figure 2 the extrapolation
of the scheme detailed of the whole boiler-solar collector.

Optimization annual of the consumptions of burnt
methane is based on the following considerations. It is
by today known and also suggested by the actually
normative, that from the technical point of view, the
installation of a boiler with accumulation to the instan-
taneous boiler place of one, allows to use a condensing
boiler with smaller installed power.

Unfortunately but, in the moments in which the
accumulation of water of the solar collector reaches the
boiler with lower temperature of that of use, the
condensing boiler it is forced to integrate the difference
of temperature heating the whole content of water of
the boiler. It is evident, that greater it is the capacity of
the boiler, greater it will be the transitory of integration
for its heating. In the transitory ones, the consumption
of burnt methane will be wasted because in the follow-
ing instant, rather short, the accumulation of water of the
boiler could be still heated from the same solar collector.

In the analysis of the installation of figure 1 have
been included, differently from the other systems of solar
integration, some advantages that bring to a further
reduction of fuel decreasing exactly the transitory afore-
said. The advantages can be reassumed this way:

- optimization of the transitory ones of integration
using a condensing boiler equipped by boiler semi rapid
of small capacity equal to 14 l connected in series to a
elliptic solar collector with accumulation incorporated
by 135 l. The assembly boiler-elliptic solar collector
with accumulation represents the optimizing elements
of the system.

- the accumulation of warm water is therefore sum
of both the capacities (boiler from 14 l + solar collector
from 135 l = 150 l). The purpose is that to always have
the elliptic solar collector to a determined level of
temperature. Besides the elliptic solar collector, exactly
for his mass of elevated water, in winter reduces
notably the possibility of freezing and summer doesn't
succeed in reaching elevated temperatures of stagnation.

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- is been of fundamental importance the choice of a
solar collector with accumulation with elliptic capturing
surface, to the purpose to optimize the absorption of
everybody of three components of the solar radiation,
for whole day and in the winter periods with low solar
altitudes. Mainly the absorption of the direct radiation
is privileged, but also that diffused and reflected, that
with the classical systems, it would be impossible to be
exploited completely.

This elliptic solar collector unlike those plane, don’t
require neither the introduction of glycol antifreeze,
neither the installation of a pomp of circulation. Then,
is not even necessary the installation of an electronic
regulator able to operate or to extinguish the pomp
appraising the difference of temperature among the
boiler and the solar collector.

Besides the elliptic solar collector demonstrate a
superior temperature of that also distributed by the city
net in the winter period. The ellipsoidal form of the
transparent dome of absorbing ago, yes that the solar
rays hit the surface with very low angles of incidence.
We avoids so the loss of energy of the total reflection

Fig. 1. Scheme of the installation of combined heating
boiler-elliptic solar collector:
1 – the condensing boiler with equipped boiler of capacity 14 l;
2 – elliptic solar collector with accumulation;
3 – incorporated boiler.

Fig. 2. Detail of the connection boiler-elliptic solar collector:
1 – boiler incorporated of 14 l in the condensing boiler,
2 – elliptic solar collector with accumulation of 135 l.

\[
\begin{align*}
G_1 &= \text{flow of water} \\
V_b &= 14 \text{ L} \\
V_c &= 135 \text{ L} \\
T_0 &= \text{cost} \\
T_i &= \text{temperature} \\
T &= \text{Sanitary warm water} \\
T_T &= \text{Cool water alimentation} \\
T( t ) &= \text{Sanitary warm water}
\end{align*}
\]
effect. The choice of this type solar collector is founded upon the following considerations: the solar ray in the impact on a transparent body can be reflected, refracted and absorbed, the angle of refraction together with that of incidence are tied up from the relationship (Kreith F. and al., 1978):

\[ \frac{\sin \alpha}{\sin \gamma} = \frac{1}{n} \]

where \( n \) points out the index of refraction of the metacrilat (elliptic absorption dome) in comparison to the air, where the index is considered unitary.

When \( \alpha > \gamma \) then the medium transparent is more refractive than air and vice versa.

When \( \alpha = 0 \) then the ray doesn’t suffer any deflection.

The index of refraction various with the wavelength of the incident ray and the single ghostly components comes refracted with different angles giving origin to the phenomenon of the dispersion. While in the passage from a medium less refractive optician (air) to a more refractive (metacrilat or glass) the luminous ray always comes refracted, not the contrary one is verified always. It exists in fact an angle limit, determined by the law of the refraction, over which a luminous ray rather than to resurface suffers a total reflection on the surface of separation of the two mediums (to see figure 3).

From the figure 4, there are deduced that in summer in the morning the plane solar collector is hit by the sun with an angle \( \alpha = \alpha_{\text{lim}} = 42^\circ \) progressively decrease until the hours 12.00 o’clock for then increase.

Considering \( n = 1.5 \) the index of refraction of the dome of metacrilat, comparable to that of the glass, the \( \sin \gamma = 1 \) (\( \gamma = 90^\circ \) when the angle of incidence \( \alpha = 42^\circ \)). We deduce therefore that the ray is not able to resurface anymore, but it is situated on the parallel one to the transparent surface in condition of total reflection. The direct radiation is not captured. We analyze such phenomenon applied to a plane solar collector in the two cases summer and winter as represented in figure 4 and then to the elliptic solar collector with accumulation in figure 5 (Duffie J.A., and al., 1978).

The absorption of the direct radiation is acceptable into the whole day. In winter instead, the absorption has been being acceptable only for the hours 9.30 at 12.00 o’clock until the hours 14.30.

Out of these timeframe he reflects completely. In the case of the ellipsoidal solar collector the differences are underlined in figure 5.

Fig. 3. Angles of incidence, reflection and refraction.

Fig. 4. Summer and winter solar excursion daily from the hours 6.00 at 12.00 o’clock – \( L = 45^\circ \).

Fig. 5. Summer solar daily excursion from the hours 6.00 at 12.00 o’clock and winter from the hours 8.00 at 12.00 o’clock – \( L = 45^\circ \).
As it can be noticed in summer the elliptic solar collector, as for that plane, it absorbs the direct radiation in the whole day capturing very well and with small angles of incidence also during the first hours of the morning, for then to fully be exploited in the whole day. From 9.00 o’clock to 12.00 o’clock the total reflection to the edges of the elliptic solar collector is verified partially, but the phenomenon is compensated by the alternation of the incidents rays between the two semiellipsoids. In winter, the radiation is absorbed, even though partially interesting the absorbing surface, from the first hours of the morning until the evening, therefore for a superior number of hours. Out of these timeframe it reflects completely. The greater ampleness of the winter solar contribution facilitates to a best integration and a greater saving of fuel. Therefore is analyzed the saving of fuel using the combination between condensing boiler-elliptic solar collector with accumulation, in comparison to a installation deprives of solar collector.

2. THERMIC AND ECONOMIC ANALYSIS OF A CONCRETE CASE (**)

In the charts I and chart II are respectively introduced in the two installations without and with solar collector, the consumptions of methane in m³, the specific costs in €/m³ and in €/day, recorded in accordance with the paid invoices in the path of 5 separate periods marked in the aforesaid charts, through the numeration from 1 to 5. For a more suggestive comparative presentation of the consumptions of methane of the two types of installation (without and with collector) during these 5 periods, in the figure 3 are introduced the diagrams of these consumptions.

Analysis has been effected on installation of figure 1, where to the condensing existing boiler 1) the elliptic solar collector has been connected to accumulation 2). The measured consumptions for the whole year in the two cases (Progetto 2000, Giugno 2001), represents the sum of the consumptions for the heating, warm sanitary water and of the kitchen. The electric energy consumption is due only to the installed pomp in the boiler and in the circuits of heating for allowing the circulation of the fluid in the installation.

The diagram of the consumptions is introduced on the following diagram of figure 6.

The data to our disposition are:
- $V_k = 51 \text{ m}^3$
- $P_c = 33.6 \text{ kW}$
- $H_i = 34.4 \text{ MJ/m}^3$
- $\eta_g = 0.79$
- $P_{c1} = 150 \text{ W}$
- $P_{c2} = 150 \text{ W}$
- $P_{sc} = 100 \text{ W}$
- $t_{fsc} = 288 \text{ K} - \text{without elliptic solar collector}$
- $t_{fsc} = 295 \text{ K} - \text{with elliptic solar collector}$
- $t_{ac} = 313 \text{ K}$
- $c_i (2004) = 0.55 \text{ €/m}^3$
- $c_i (2005) = 0.57 \text{ €/m}^3$
- $c_{el} = 0.085 \text{ €/kWh}$
- $i = 2.64\%$
- $n = 15 \text{ years}$
- $C_i''=1.200,00 \text{ €}$

In the charts III a, b are underlined the numerical values of comparison calculated in the two cases with and without elliptic solar collector and the economic analysis.

### Chart I. Consumptions of methane and specific costs in the installation without elliptic solar collector

<table>
<thead>
<tr>
<th>Progressive addition</th>
<th>period of two-months utilization</th>
<th>consumption of methane m³</th>
<th>cost €</th>
<th>days</th>
<th>specific cost of methane €/m³</th>
<th>specific cost daily €/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>01/01/04 - 31/03/04</td>
<td>1203</td>
<td>550.00</td>
<td>90</td>
<td>0.46</td>
<td>6.11</td>
</tr>
<tr>
<td>2</td>
<td>01/04/04 - 28/06/04</td>
<td>161</td>
<td>105.00</td>
<td>89</td>
<td>0.65</td>
<td>1.18</td>
</tr>
<tr>
<td>3</td>
<td>29/06/04 - 29/09/04</td>
<td>112</td>
<td>28.00</td>
<td>93</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>4</td>
<td>30/09/04 - 23/12/04</td>
<td>900</td>
<td>579.24</td>
<td>84</td>
<td>0.64</td>
<td>6.90</td>
</tr>
<tr>
<td>5</td>
<td>24/12/04 - 31/12/04</td>
<td>96</td>
<td>64.36</td>
<td>8</td>
<td>0.67</td>
<td>8.05</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td></td>
<td><strong>2472</strong></td>
<td><strong>1326.60</strong></td>
<td><strong>364</strong></td>
<td><strong>0.54</strong></td>
<td><strong>3.64</strong></td>
</tr>
</tbody>
</table>

### Chart II. Consumptions of methane and specific costs in the installation with elliptic solar collector

<table>
<thead>
<tr>
<th>Progressive addition</th>
<th>period of two-months utilization</th>
<th>consumption of methane m³</th>
<th>cost €</th>
<th>days</th>
<th>specific cost of methane €/m³</th>
<th>specific cost daily €/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>01/01/05 - 31/03/05</td>
<td>1094</td>
<td>531.05</td>
<td>90</td>
<td>0.49</td>
<td>5.90</td>
</tr>
<tr>
<td>2</td>
<td>01/04/05 - 28/06/05</td>
<td>104</td>
<td>68.55</td>
<td>89</td>
<td>0.66</td>
<td>0.77</td>
</tr>
<tr>
<td>3</td>
<td>29/06/05 - 29/09/05</td>
<td>51</td>
<td>38.25</td>
<td>93</td>
<td>0.75</td>
<td>0.41</td>
</tr>
<tr>
<td>4</td>
<td>30/09/05 - 23/12/05</td>
<td>720</td>
<td>468.00</td>
<td>84</td>
<td>0.65</td>
<td>5.57</td>
</tr>
<tr>
<td>5</td>
<td>24/12/05 - 31/12/05</td>
<td>87</td>
<td>61.09</td>
<td>8</td>
<td>0.70</td>
<td>7.64</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td></td>
<td><strong>2046</strong></td>
<td><strong>1166.95</strong></td>
<td><strong>364</strong></td>
<td><strong>0.57</strong></td>
<td><strong>3.21</strong></td>
</tr>
</tbody>
</table>

(**) Installation of heating with elliptic solar collector with accumulation of the house in Via Bellinzago 48A - Novara-Italy.
Consumptions of methane with and without elliptic solar collector

![Graph showing consumption of methane](image)

**Fig. 6.** Comparison of the consumptions with and without elliptic solar collector.

**Chart III.** Numerical values for both the choices with and without elliptic solar collector collector

### Boiler condensing without elliptic solar collector

- **Summer period from 01/04/04 to 29/09/04**
  - Consumption of fuel due to the consumption of sanitary warm water
    - $V_{cse} = V_{cse}/46 - V_k = 117,00 \text{ m}^3$
    - $Q_{s'} = V_{cse} \cdot H \cdot n_k = 3179,59 \text{ MJ}$
    - $Q_{s'} = 2Q_{s'} = 6359,18 \text{ MJ}$
    - $t_{summer} = t_{summer}/T = 26,28 \text{ h}$
    - $m_{water'} = Q_{s'}/c_p(t_{ac} - t_{fsc}) = 30426,72 \text{ l}$
    - $C_{se'} = V_{cse} \cdot C_c = 64,35 \text{ €}$
    - $C_{si'} = V_{csi} \cdot C_c = 64,35 \text{ €}$
    - $C_{r'} = (V_{ct} - V_{cse} - V_{csi} - 2V_k) \cdot C_c = 1174,80 \text{ €}$
    - $C_{t'} = C_{si'} + C_{se'} + C_{r'} = 1303,50 \text{ €}$
    - $P_{els'} = 2 \cdot t_{summer} \cdot P_{elpc} = 5,26 \text{ kWh}$
    - $C_{els'} = P_{els'} \cdot C_e = 0,45 \text{ €}$
    - $Q_{r'} = (V_{ct} - V_{cse} - V_{csi} - 2V_k) \cdot H \cdot \eta_g = 58047,94 \text{ MJ}$
    - $t_{winter} = t_{winter}/T = 479,74 \text{ h}$
    - $m_{water''} = Q_{r'}/c_p(t_{ac} - t_{fcc}) = 9210,37 \text{ l}$
    - $C_{r'} = (V_{ct} - V_{cse} - V_{csi} - 2V_k) \cdot C_c = 1079,01 \text{ €}$
    - $C_{t'} = C_{si'} + C_{se'} + C_{r'} = 1108,08 \text{ €}$
    - $C_{g'} = C_{t'} + C_{els'} = 1322,56 \text{ €}$

### Boiler condensing with elliptic solar collector

- **Summer period from 01/04/05 to 30/09/05**
  - Consumption of fuel due to the consumption of sanitary warm water
    - $V_{cse} = V_{cse}/46 - V_k = 25,50 \text{ m}^3$
    - $Q_{s'} = V_{cse} \cdot H \cdot n_k = 692,99 \text{ MJ}$
    - $Q_{s'} = 2Q_{s'} = 1385,98 \text{ MJ}$
    - $t_{summer} = t_{summer}/T = 5,73 \text{ h}$
    - $m_{water'} = Q_{s'}/c_p(t_{ac} - t_{fsc}) = 30426,72 \text{ l}$
    - $C_{se'} = V_{cse} \cdot C_c = 14,54 \text{ €}$
    - $C_{si'} = V_{csi} \cdot C_c = 14,54 \text{ €}$
    - $C_{r'} = (V_{ct} - V_{cse} - V_{csi} - 2V_k) \cdot C_c = 1079,01 \text{ €}$
    - $C_{t'} = C_{si'} + C_{se'} + C_{r'} = 1108,08 \text{ €}$
    - $P_{els'} = 2 \cdot t_{summer} \cdot P_{elpc} = 1,15 \text{ kWh}$
    - $C_{els'} = P_{els'} \cdot C_e = 0,10 \text{ €}$
    - $Q_{r'} = (V_{ct} - V_{cse} - V_{csi} - 2V_k) \cdot H \cdot \eta_g = 51444,17 \text{ MJ}$
    - $t_{winter} = t_{winter}/T = 425,16 \text{ h}$
    - $m_{water''} = Q_{r'}/c_p(t_{ac} - t_{fcc}) = 9210,37 \text{ l}$
    - $C_{r'} = (V_{ct} - V_{cse} - V_{csi} - 2V_k) \cdot C_c = 1079,01 \text{ €}$
    - $C_{t'} = C_{si'} + C_{se'} + C_{r'} = 1108,08 \text{ €}$
    - $C_{g'} = C_{t'} + C_{els'} = 1322,56 \text{ €}$

It is necessary besides to specify, that when the elliptic solar collector is installed, in the 6 summer months from 01/04/04 to 30/09/04, the production of warm sanitary water is practically free. The condensing boiler always results power off. Then, the difference of the consumption of fuel indicated in the chart II compared to chart I, simply is due to the use of the kitchen. We know therefore that this consumption corresponds to around 18 m³/months for 3 people, that in three months corresponds at $V_k = 51 \text{ m}^3$, the...
consumption of warm sanitary water is obtained subtracting this value from the data of the chart II. Admitting that such consumption is also identical in the devoid case of elliptic solar collector, it will come subtracted of the indicated consumption in chart I in same period. In the chart III, the cost of the solar collector also includes the manpower for the assemble in comparison to the installation without solar collector. Subsequently in the same chart they underline:

- the real saving of fuel equal to 15%.
- the number of years of amortization “n”, in the hypothesis that the investment is sustained with own funds and that the cost of the money is maintained constant in the time and equal to i = 2,64%, is obtained calculating at first the NPV, then the value of the parameter PVa in the hypothesis of a duration of the elliptic solar collector of n = 15 with i = 2,64%, extracting from the charts in literature of specialty (Bodt, 1969). The time of return of the investment corresponds at the year when the NPV annuls it
- the rate interns of efficiency i* = IRR

The form and the dimensions of the elliptic solar collector are introduced in the figures 7a and 7b.

![Fig. 7a. Elliptic solar collector assembled.](image)

**Fig. 7b.** 1 – dome in metacrilat; 2 – double plate in metacrilat; 3 – gasket; 4 – reservoir 135 l; 5 – isolated container; 6 – magnesium anode; 7 – safety and non return valve; 8 – adjustable handle; 9 – adjustable support.

3. CONCLUSIONS

The value of the cash flows updated until to the useful life of the solar collector said also Net Present Value or NPV results positive. The maximum value of the interest that assures us the possibility to take money loan, without going in loss it corresponds to what the NPV annuls. Such interest is said IRR = i*, and results of 14%. The indicators NPV and IRR point out both that the investment is convenient. The pay back time of the investment represents the year when the elliptic solar collector is amortized and it is that to which corresponds the annulment of the NPV.

The investment is amortized among 6° and the 7° year. He doesn't need besides, to neglect the climatic variation of year in year. In fact the value of the degrees day in the period of heating in the year 2003/04 and in the year 2004/05, are respectively equal to 2286 GG and 2436 GG (Meteorological bulletin, 2004, 2005). The difference percentage of these two values is of 7%.

This shows, that the year 2004/05 have middle been more cold of the precedent and has influenced the consumptions of 5,8% in more.

Therefore, the energetic saving calculated of 15% must have increased of this percentage becoming equal to 19%. The annual saving of fuel is ranked around with that obtainable with the use of the plane solar collectors in the same case, but with the difference that economically the return of the investment decidedly results more quick. The elliptic solar collector demonstrates efficacy, for working into the whole year.

The calculations of this study could be more accurate, if in the future the consumptions of fuel were valued for an ampler time interval, considering the rate of inflation of the energetics products and the government incentives bonus.

**Nomenclature**

- \(C_{ch}^+\) cost of electric energy of heating period without elliptic solar collector .................. [€]
- \(C_{ch}^-\) cost of electric energy of summer or winter period expense for utilising warm water without elliptic solar collector ........ [€]
- \(C_{ch}^\prime\) cost of electric energy of heating period with elliptic solar collector ......................... [€]
- \(C_{ch}^\prime\prime\) cost of electric energy of summer or winter period expense for utilizing warm water with elliptic solar collector ............ [€]
- \(C_g\) global cost of electric and thermic energy for case without elliptic solar collector .......... [€]
- \(C_g^\prime\) global cost of electric and thermic energy for case with elliptic solar collector .............. [€]
- \(C_i^\prime\) cost of the investment for installing the elliptic solar collector ................................. [€]
- \(c_p\) specific heat of the thermovector fluid ......................................................... [MJ kg\(^{-1}\) K\(^{-1}\)]
- \(c_e\) specific cost of fuel ................................................. [€ m\(^{-3}\)]
- \(c_{el}\) specific cost of electric energy ................... [€ kWh\(^{-1}\)]
- \(H_i\) net heat value of fuel ........................................ [MJ m\(^{-3}\)]
- \(m_{water}^+\) mass of warm water utilized in the case without elliptic solar collector ............ [l]
- \(m_{water}^\prime\) mass of warm water mass utilized in the case without elliptic solar collector ............ [l]
- \(P_c\) thermic power of a condensing boiler .... [kW]
electric power of the pomp of 1° zone ........... [W]

P_{elp2} electric power of the pomp of 2° zone ........... [W]

P_{elpc} electric power of the pomp of the condensing boiler ............................................ [W]

P_{elsh} electric power consumption of the pomp of boiler for production warm water without elliptic solar collector .................... [kWh]

P_{elsh2} electric power consumption of the pomp of boiler for production warm water without elliptic solar collector .................... [kWh]

P_{elsh3} electric power consumption of the pomp of boiler for production warm water with elliptic solar collector ........................................... [kWh]

P_{elsh32} electric power consumption of the pomp of boiler for production warm water with elliptic solar collector ........................................... [kWh]

P_{elsh33} electric power consumption of the pomp of boiler for production warm water with elliptic solar collector ........................................... [kWh]

P_{elsh332} electric power consumption of the pomp of boiler for production warm water with elliptic solar collector ........................................... [kWh]

Q_{sh} heating quantity needed for production of warm water without elliptic solar collector ........................................... [MJ]

Q_{sh2} heating quantity needed for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh3} heating quantity for whole year necessary for production of warm water without elliptic solar collector ........................................... [MJ]

Q_{sh32} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh33} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh332} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh333} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh4} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh42} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh5} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh52} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh53} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh532} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh533} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

Q_{sh5332} heating quantity for whole year necessary for production of warm water with elliptic solar collector ........................................... [MJ]

q_{sh} heating quantity for the whole year for production of warm water with elliptic solar collector ........................................... [MJ]

\textit{t_{summer}} operating dailing time of the condensing boiler in summer period ........................................... [h\cdot g^{-1}]

\textit{t_{winter}} operating dailing time of the condensing boiler in winter period ........................................... [h]

\textit{t_{winter/day}} operating dailing time of the condensing boiler in winter period ........................................... [h\cdot g^{-1}]

T six months summer period of the condensing boiler ........................................... [h]

V_{at} total volum of methane consumed for the whole year for production of warm water and heating recorded to the paid invoices ........................................... [m^3]

V_{at2} total volum of methane consumed for production of warm water in winter period recorded to the paid invoices ........................................... [m^3]

V_{at3} total volum of methane consumed for production of warm water in summer period recorded to the paid invoices ........................................... [m^3]

V_{at4} total volum of methane consumed for production of warm water in winter period recorded to the paid invoices ........................................... [m^3]

V_{at5} total volum of methane consumed for production of warm water in summer period recorded to the paid invoices ........................................... [m^3]

PV_{a(n, i)} annual factor ........................................... [%]

NPV net present value ........................................... [€]

IRR=i* rate intern of efficiency ........................................... [%]

Greek symbols

\eta_s season efficiency of the condensing boiler

BIBLIOGRAPHY